5.0 HYDROLOGIC ANALYSIS

The total area of Morrison Cove is approximately 185 square miles. There are four major watersheds in Morrison Cove, which include Piney Creek, Clover Creek, Halter Creek, and Yellow Creek (Table 5-1, Figure 5-1). Additionally, Schmucker Run and three unnamed tributaries discharge directly into the Frankstown Branch Juniata River. The characteristics of the major watersheds within Morrison Cove are summarized in Table 5-1. Streams are preferentially oriented along the bedrock strike throughout most of Morrison Cove.

Table 5-1. Major Watersheds in Morrison Cove

Major Watersheds	Outlet Elevation[1] (Feet)	Drainage Area (sq mi)
Piney Creek	850	25.4
Clover Creek	805	50.1
Halter Creek	1,060	32.1
Yellow Creek	1,110	69.2
Schmucker Run	800	2.6
Drainage to Frankstown Branch Juniata River		5.6

[1] Outlet elevations are based on USGS topographic maps and measured at the location where the stream leaves Morrison Cove.

Halter Creek has two tributaries within Morrison Cove, which include Cabbage Creek and Plum Creek. Yellow Creek has four tributaries within Morrison Cove, which include Hickory Bottom Creek, Beaver Creek, Three Spring Run, and Potter Creek. The areas of the tributaries were presented in Table 5-2 and shown graphically in Figure 5-2.

Table 5-2. The Secondary Watersheds in the Halter Creek and Yellow Creek Watersheds and Their Drainage Areas

Major Watersheds	Secondary Watersheds (Tributaries)	Drainage Area (sq mi)
Halter Creek	Cabbage Creek	4.0
	Plum Creek	17.4
Yellow Creek	Hickory Bottom Creek	7.3
	Beaver Creek	19.1
	Three Spring Run	9.8
	Potter Creek	13.3

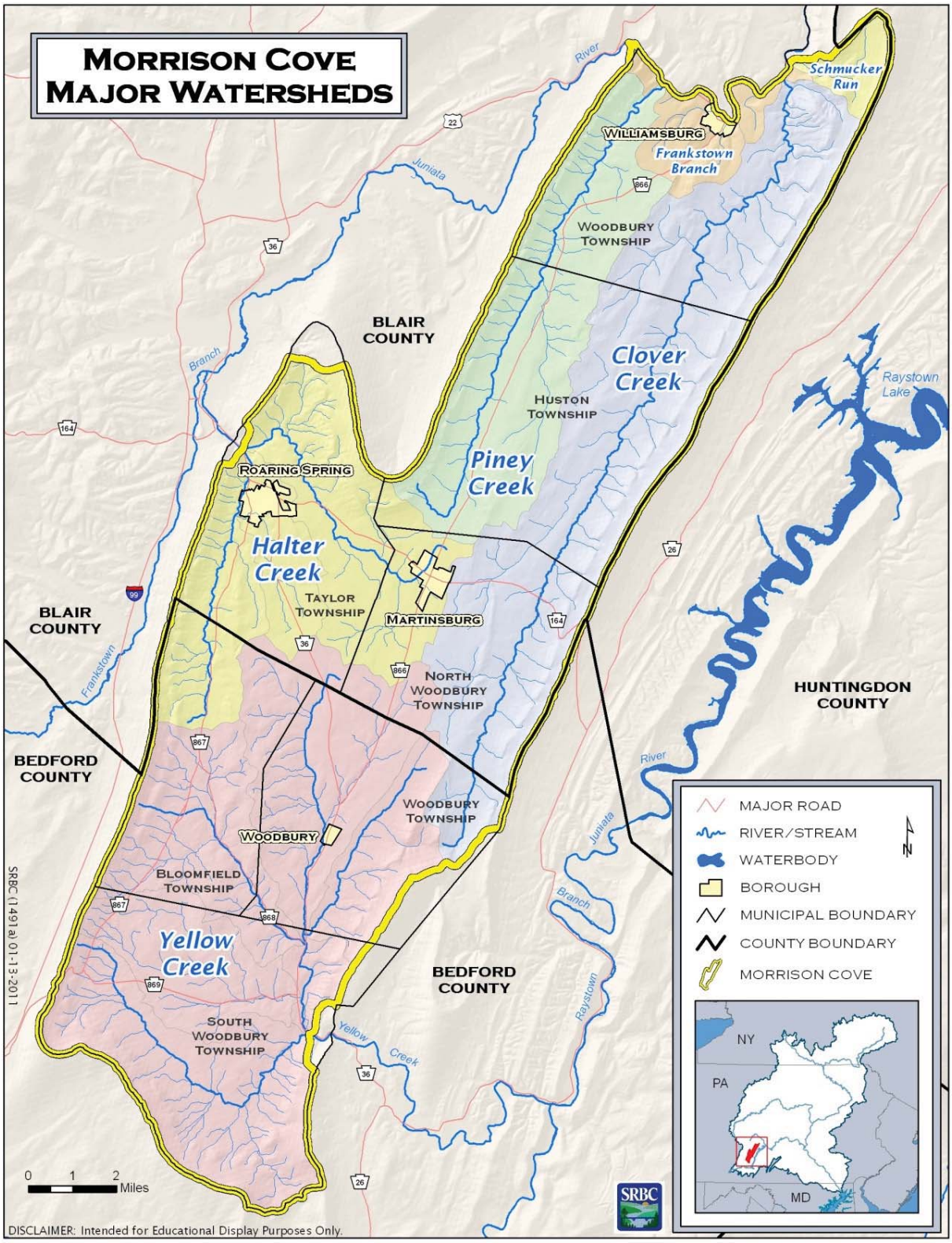

Figure 5-1. Major Watersheds in Morrison Cove

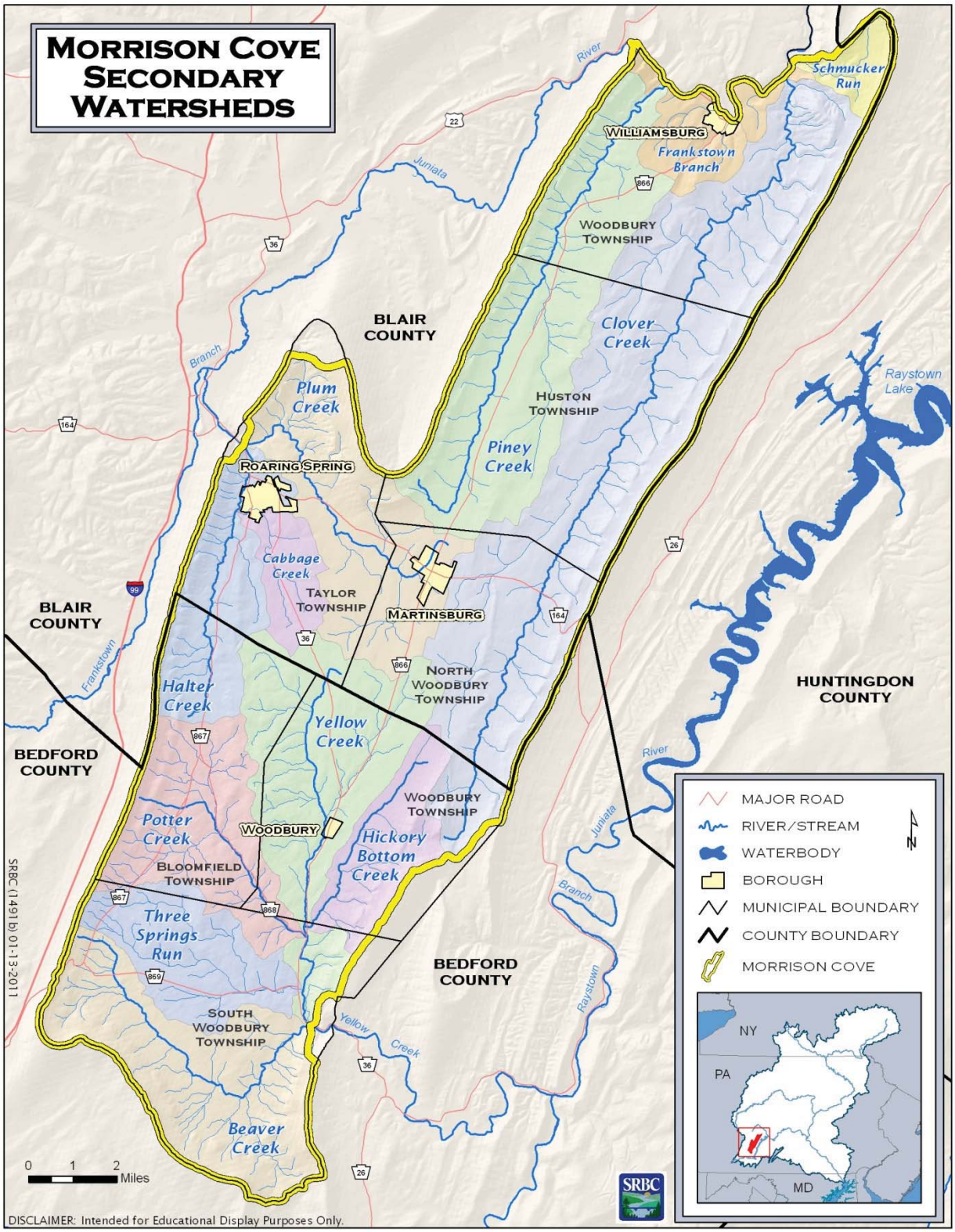

Figure 5-2. Secondary Watersheds in Morrison Cove

5.1 Streamflow Statistics

The outlets of three major watersheds, Piney Creek, Clover Creek, and Yellow Creek, were gaged to assess streamflow in the Morrison Cove area. Halter Creek was gaged upstream of the confluence of Halter Creek and Plum Creek. Plum Creek was also gaged. In addition, HC-PC-Reservoir UNT, an unnamed tributary near Martinsburg, was monitored to provide information on streamflow from the Bald Eagle, Juniata, and Tuscarora Formations. The locations of the aforementioned temporary gages are shown in Figure 5-3. Stream stages and temperatures were measured at 10-minute intervals continuously, from April 2009 through December 2009, at each temporary gage. It should be noted that although the monitoring interval at Halter Creek was 10-minute, only daily flows were obtained at this gage. This is because flow from Roaring Spring was primarily consumptively used which was only available on a daily basis. The daily consumptive use was added back to calculate flow at Halter Creek. The exact monitoring period and number of observations vary for each temporary gage due to site vandalism and equipment malfunctions. Rating curves were developed based on streamflow gaging at various stages for each temporary gage. All data were reviewed for accuracy and suspect data points were removed from the data. Daily mean flows were then calculated. Information of the temporary gage records is shown in Table 5-3 and summarized below.

Table 5-3. Information for the Temporary Gage Records

Temporary Gage	Period of Record	Monitoring Interval	Number of Observations
Piney Creek	Jun. 10, 2009 to Dec. 15, 2009	10 minutes	25,787
Clover Creek	Apr. 1, 2009 to Dec. 15, 2009	10 minutes	33,473
Halter Creek	Apr. 1, 2009 to Dec. 15, 2009	Daily	259
Plum Creek	Apr. 1, 2009 to Dec. 15, 2009	10 minutes	35,755
Yellow Creek	Apr. 1, 2009 to Dec. 15, 2009	10 minutes	35,306
HC-PC-Reservoir UNT	Apr. 30, 2009 to Dec. 15, 2009	10 minutes	29,661

Piney Creek (PC-1)

Piney Creek stilling well was located on the eastern abutment of Blair County Bridge 20 on Wertz Road. The start of PC-1 flow monitoring was delayed until June 10, 2009, due to site vandalism.

Clover Creek (CC-1)

Clover Creek stilling well was located on the Cove Forge Church property, east of Williamsburg.

Halter Creek (HC-1)

Halter Creek flows were measured in a stilling well in the pool behind a permanent, 14-foot-wide sharp-crested weir. The weir was located approximately 100 feet above the confluence of Halter Creek and Plum Creek. This temporary gage has been operated on a monthly basis since 1995. The 10-minute interval monitoring started on March 20, 2009 and ended on January 20, 2010. More than 80 percent of Roaring Spring flow was not accounted for

by the HC-1 weir due to the combination of consumptive use by the Roaring Spring Bottling Company and Appleton Paper Company and discharge of Appleton Paper Company wastewater into the Frankstown Branch Juniata River.

Plum Creek (HC-PC-1)

Plum Creek joins Halter Creek as it exits Morrison Cove at McKee Gap. Plum Creek is entirely contained within Morrison Cove. Plum Creek flows were measured in a stilling well in the pool behind a permanent, 15-foot-wide sharp-crested weir. The weir at HC-PC-1 was about 100 feet above the confluence of Halter Creek and Plum Creek. Monthly measurements started in 1995. The 10-minute interval monitoring started on March 20, 2009 and ended on January 20, 2010.

Yellow Creek (YC-1)

The Yellow Creek stilling well was located on the Randy and Gloria Smith property in Loysburg within the Loysburg Gap. YC-1 flow monitoring started on March 20, 2009 and ended on January 20, 2010.

HC-PC-Reservoir UNT

Flow at HC-PC-Reservoir UNT went through a concrete culvert. The water level and specific conductance were monitored above the culvert. The monitoring started on April 30, 2009 and ended on December 15, 2009.

The daily average flows at the six temporary gages were then computed based on the recorded measurements (Figure 5-4). It should be noted that the y-axis of the sub-plots of Figure 5-4 has a different scale due to the different flow ranges at various temporary gages. The x-axis was the same for all the sub-plots. The daily average flows in cubic feet per second per square mile (csm), are shown in Figure 5-5. While the flow records did not cover a complete year (either water year or calendar year), the records spanned the high flow months of March through June, and the low flow months of July through October. Therefore, the streamflow statistics computed from the field data were determined to be representative of hydrologic conditions in 2009 within Morrison Cove. Table 5-4 summarizes streamflow statistics computed from the temporary gage data.

Table 5-4. Streamflow Statistics Computed From Temporary Gage Data (cfs)

Temporary Gage	Average	Standard deviation	Minimum	Median	Maximum
Piney Creek	16.2	7.1	9.5	14.0	66.4
Clover Creek	33.2	16.5	11.2	31.7	97.0
Halter Creek	17.4	6.2	10.8	15.4	49.6
Plum Creek	13.8	12.3	1.8	8.9	61.8
Yellow Creek	50.6	22.6	25.9	45.8	140.5
HC-PC_ReservoirUNT	0.23	0.21	0.03	0.15	1.31

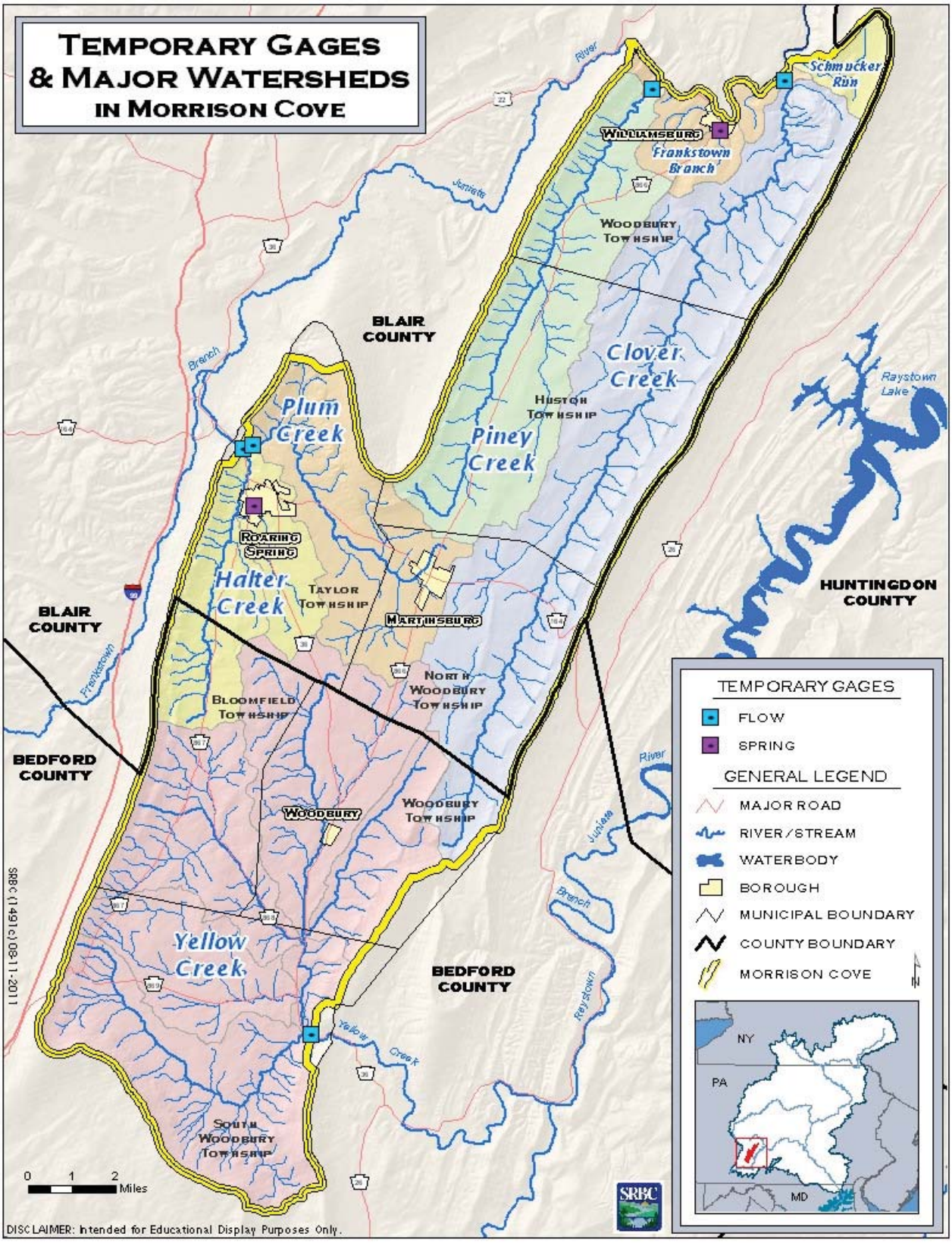

Figure 5-3. Locations of Morrison Cove Temporary Gages

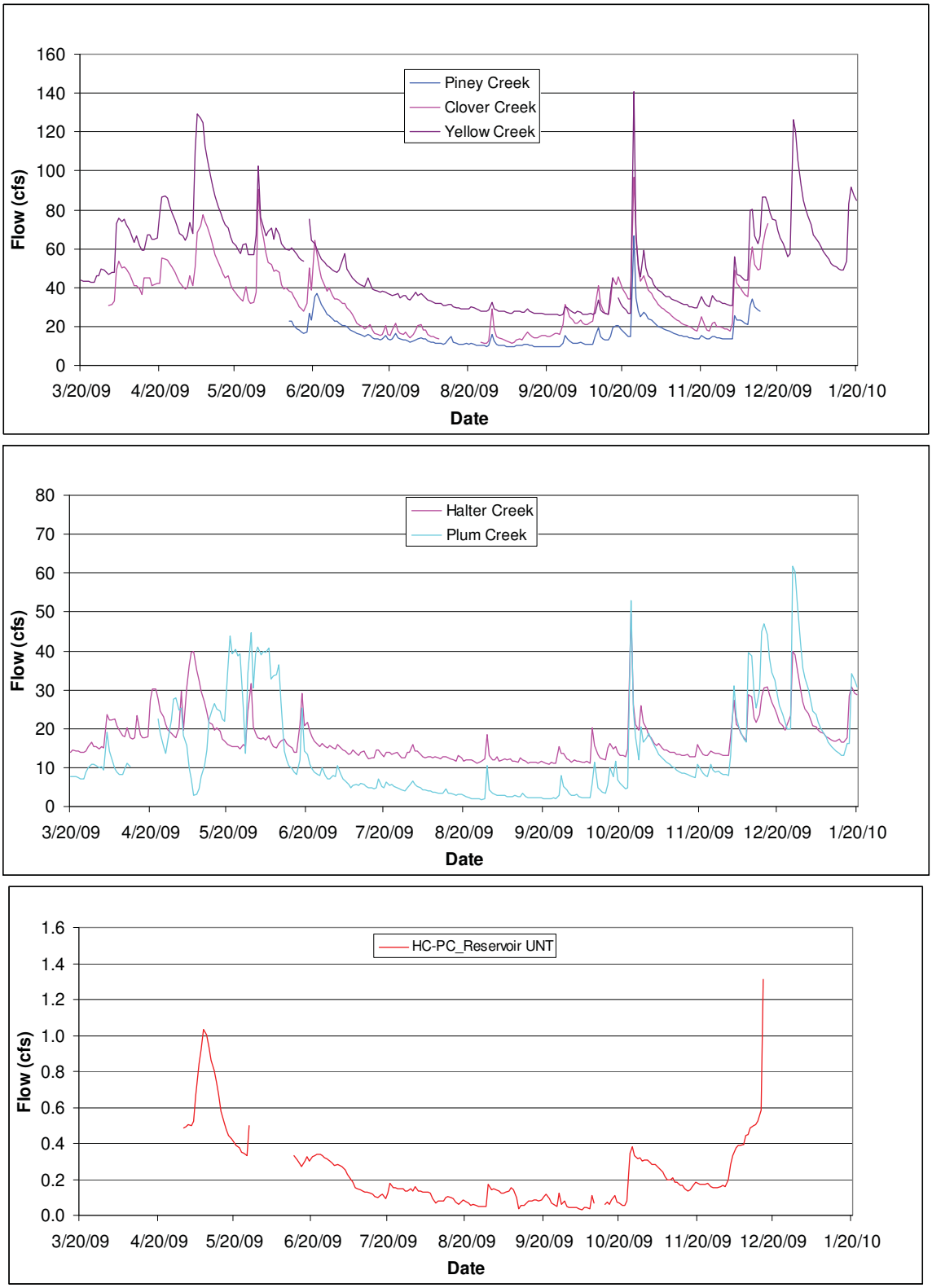

Figure 5-4. The Daily Average Flow in the Temporary Gages

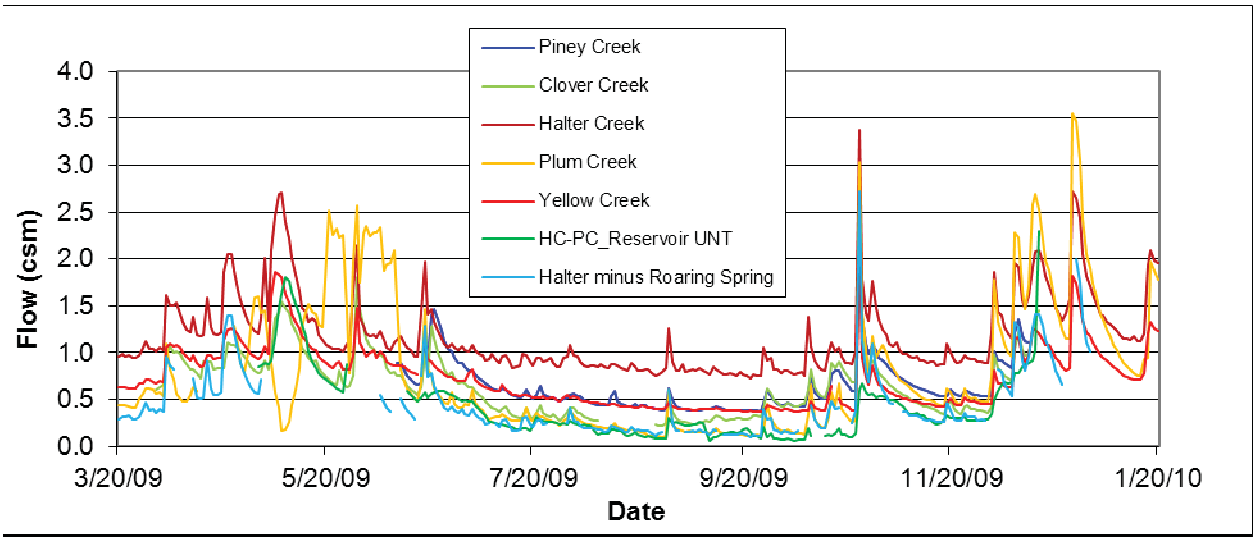

Figure 5-5. Comparison of Daily Average Flow in csm at the Temporary Gages

5.2 Recurrence Interval Analysis

SRBC employs various streamflow statistics for a wide range of purposes for water resources management and planning (SRBC, 2006; Zhang et al., 2010). The commonly used statistics include the monthly exceedance percentiles, 10-year base flow, 7Q10, and average daily flow (ADF) (Pyrce, 2004). The monthly exceedance percentiles estimated in this study included P95, P90, P85, P80, P75, P70, P65, P60, and P50. For example, monthly P90 is the streamflow that is exceeded 90 percent of the time for the month. The 10-year base flow is the 10-year recurrence interval minimum base flow. 7Q10 is the tenth percentile of the distribution of annual minimum 7-day average flows, i.e., the recurrence interval is 10 years (Riggs, 1980).

Typically, at least 10 years of continuous daily streamflow records are required to reliably estimate low flow statistics, such as 7Q10 and the 10-year base flow, using frequency analysis (Riggs, 1972). The records from the six temporary gages in Morrison Cove were less than one year, and thus were not sufficient to estimate low flow statistics with frequency analysis. Low flow statistics could be accurately estimated if continuous operation at the six temporary gages were to continue for a long time period. However, for the purpose of this study, the information was needed sooner. One common solution to this dilemma is the use of information transfer techniques to estimate low flow statistics for the streams in Morrison Cove. These information transfer techniques relate streamflow measurements during base flow conditions at the temporary gages without long-term continuous records with concurrent streamflow measurements at selected nearby gages with long-term continuous records. The temporary gages without long-term continuous records are often referred to as low-flow partial-record stations. The selected nearby long-term gages are referred to as reference gages (or index gages).

Commonly used information transfer methods for estimating low flow statistics for low flow partial-record stations include the base flow correlation method proposed by Stedinger and

Thomas (1985) and the flow ratio approach (Q-ratio) suggested by Potter (2001). The base flow correlation method was recommended by the U.S. Geological Survey (USGS) Office of Surface Water (1985). The Q-ratio method was initially developed by Potter (2001). Ries and Eng (2010) employed a modified Q-ratio method.

Generally, about 10 streamflow measurements during base flow conditions at the low flow partial-record stations over a period of three years are preferred for the base flow correlation method (Riggs, 1972; Zhang and Kroll, 2007). In this study, temporary gages were operated continuously. Although there was only one year of record, sufficient number of base flow measurements were obtained to permit the estimation of low flow statistics. Six candidate reference gages were used and are shown in Table 5-5. Commonly used statistics including ADF, 7Q10, 10-year base flow, and various monthly percentiles were estimated in this study. The estimated ADF, 7Q10, and 10-year base flow at the temporary gages in Morrison Cove are shown in Table 5-6. Figure 5-6 shows an example of the monthly streamflow percentiles for Clover Creek. The monthly percentiles for other streams are included in the appendix.

Table 5-5. Reference Gages Used in the Study

USGS #	Gage Name	Drainage Area (sq mi)	Record
01556000	Frankstown Br Juniata River at Williamsburg, PA	291	1916-current
01557500	Bald Eagle Creek at Tyrone, PA	44	1944-current
01558000	Little Juniata River at Spruce Creek, PA	220	1938-current
01559000	Juniata River at Huntingdon, PA	816	1941-current
01560000	Dunning Creek at Belden, PA	172	1939-current
01562000	Raystown Branch Juniata River at Saxton, PA	756	1911-current

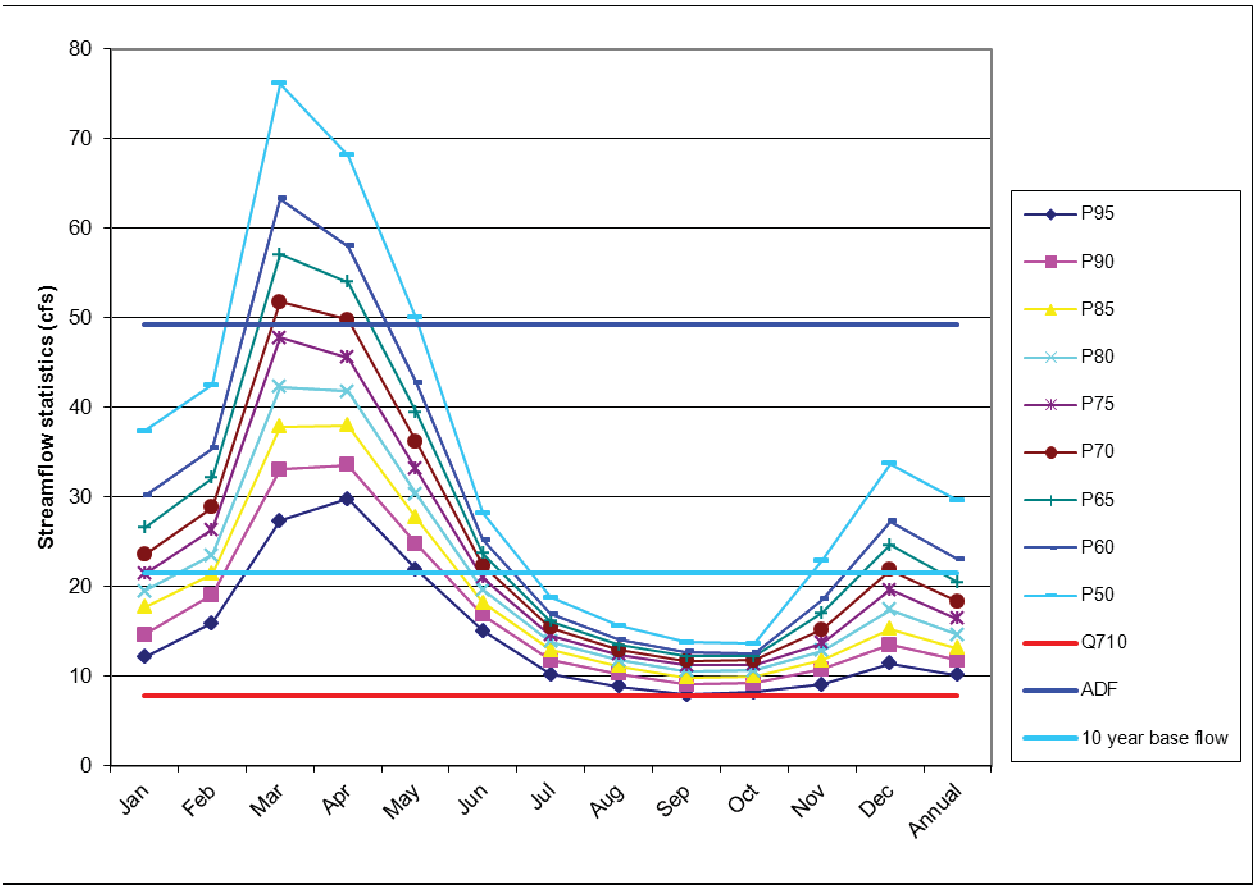

Figure 5-6. Estimate of Selected Streamflow Statistics for Clover Creek

Table 5-6. Estimate of Selected Streamflow Statistics for the Temporary Gages

Temporary Gage	Reference Gage	Concurrent Streamflows	Correlation Coefficient	7Q10 (cfs)	ADF (cfs)	10-year Base Flow (cfs)
Halter Creek	01556000	10	0.915	3.3	27.3	10.6
Plum Creek	01556000	13	0.931	2.2	17.9	6.9
Piney Creek	01558000	5	0.991	6.2	39.9	19.6
Clover Creek	01559000	7	0.966	7.8	49.2	21.5
Yellow Creek	01562000	14	0.920	10.2	140.7	46.8
HC-PC-Reservoir	01556000	5	0.995	0.07	0.56	0.22